(NASA-CR-160286) SPACE CONSTRUCTION SYSTEM ANALYSIS, FINAL REVIEW. PART 1: EXECUTIVE SUMMARY (Rockwell International Corp., Canoga Park) 50 p HC A03/MF A01 CSCL 22A
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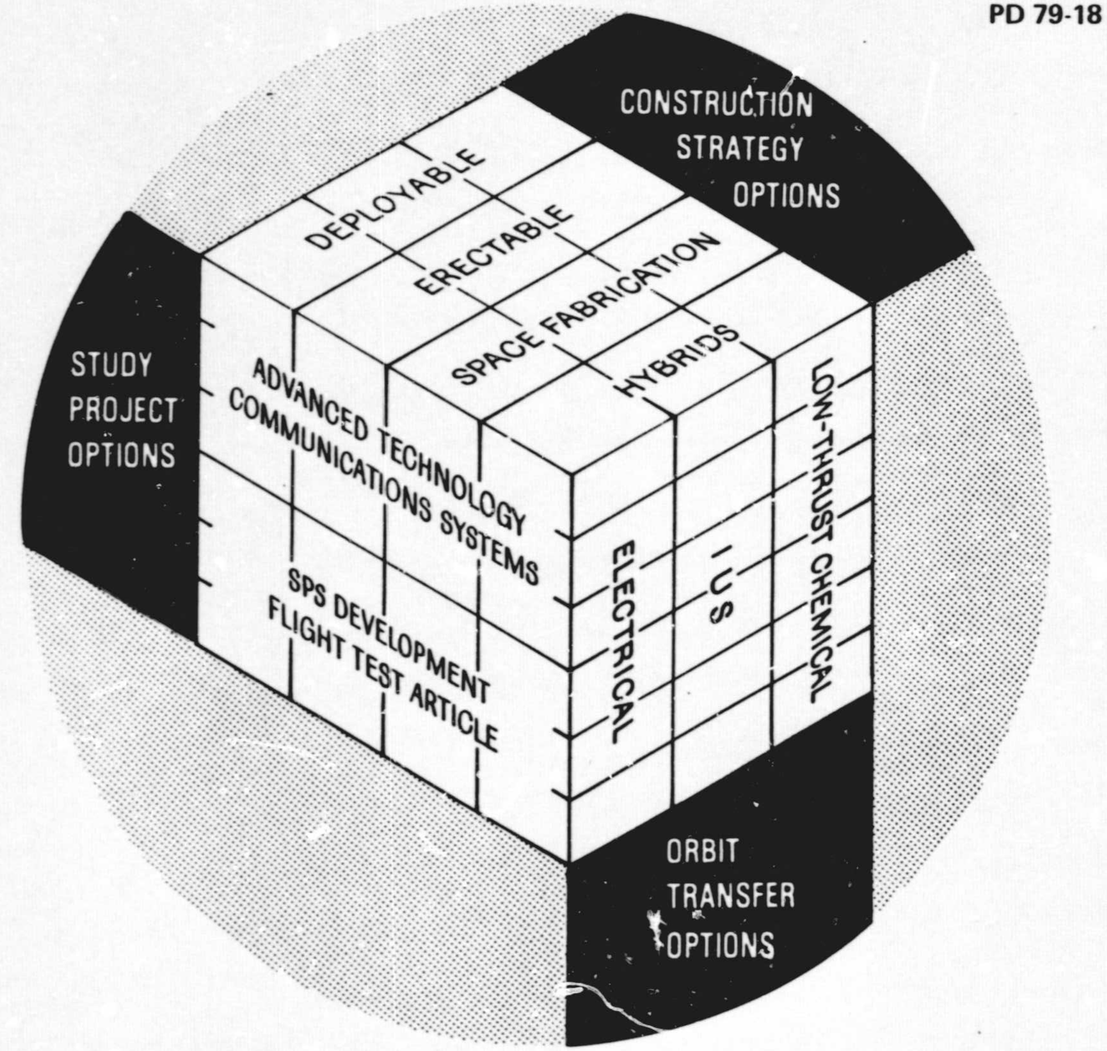
SPACE CONSTRUCTION SYSTEM ANALYSIS
FINAL REVIEW, PART I
EXECUTIVE SUMMARY

PD 79-18



Satellite Systems Division
Space Systems Group
Rockwell International

FOREWORD

In September, 1979, NASA/JSC awarded the subject contract, Space Construction Systems Analysis (NAS9-15718) to the Space Systems Group of Rockwell International. The contract is being performed in two parts, each nine months in duration. This report is an excutive summary of Part I.

STUDY OBJECTIVES

This chart shows the three principal objectives of Part I of the subject study.

The first objective was to define several large space system projects which would drive out specific requirements for space construction. The second objective was to develop a data base for the kinds of construction methods appropriate to building the project systems. The purpose of the data base is to provide the designers of future large systems with a convenient systematic access to methods of space construction and associated requirements. The third objective had the purpose of expanding the study results to applications other than the study projects.

These objectives have now been achieved; this report summarizes the major products of Part I which are treated in detail in the following documentation:

- Project Systems and Mission Descriptions, SSD 79-0077, March 1979
- Space Construction System Analysis Part I Final Review, PD79-18, June 26, 1979
- Space Construction System Analysis, System Analysis of Space Construction, SSD 79-0123, June 1979
- Space Construction System Analysis, Construction System Shuttle Integration, SSD 79-0124, June 1979
- Space Construction System Analysis, Construction Methods Data Base, SSD 79-0125, June 1979
- Space Construction System Analysis, Special Emphasis Studies, SSD 79-0126, June 1979

Part II will be discussed later in this summary.

STUDY OBJECTIVES

PART I

PROJECT SYSTEMS DEFINITION

- ESTABLISH PROJECT CONSTRUCTION REQUIREMENTS

CONSTRUCTION ANALYSIS

- DEVELOP CONSTR. METHODS DATA BASE

GENERIC CONCEPT ASSESSMENT

- DETERMINE "BREAK-POINTS" FOR VARIOUS TYPES OF LARGE SYSTEMS

PART II

- SELECTED PROJECT SYSTEM(S)
- END-TO-END CONSTRUCTION
- DEVELOPMENT PLAN

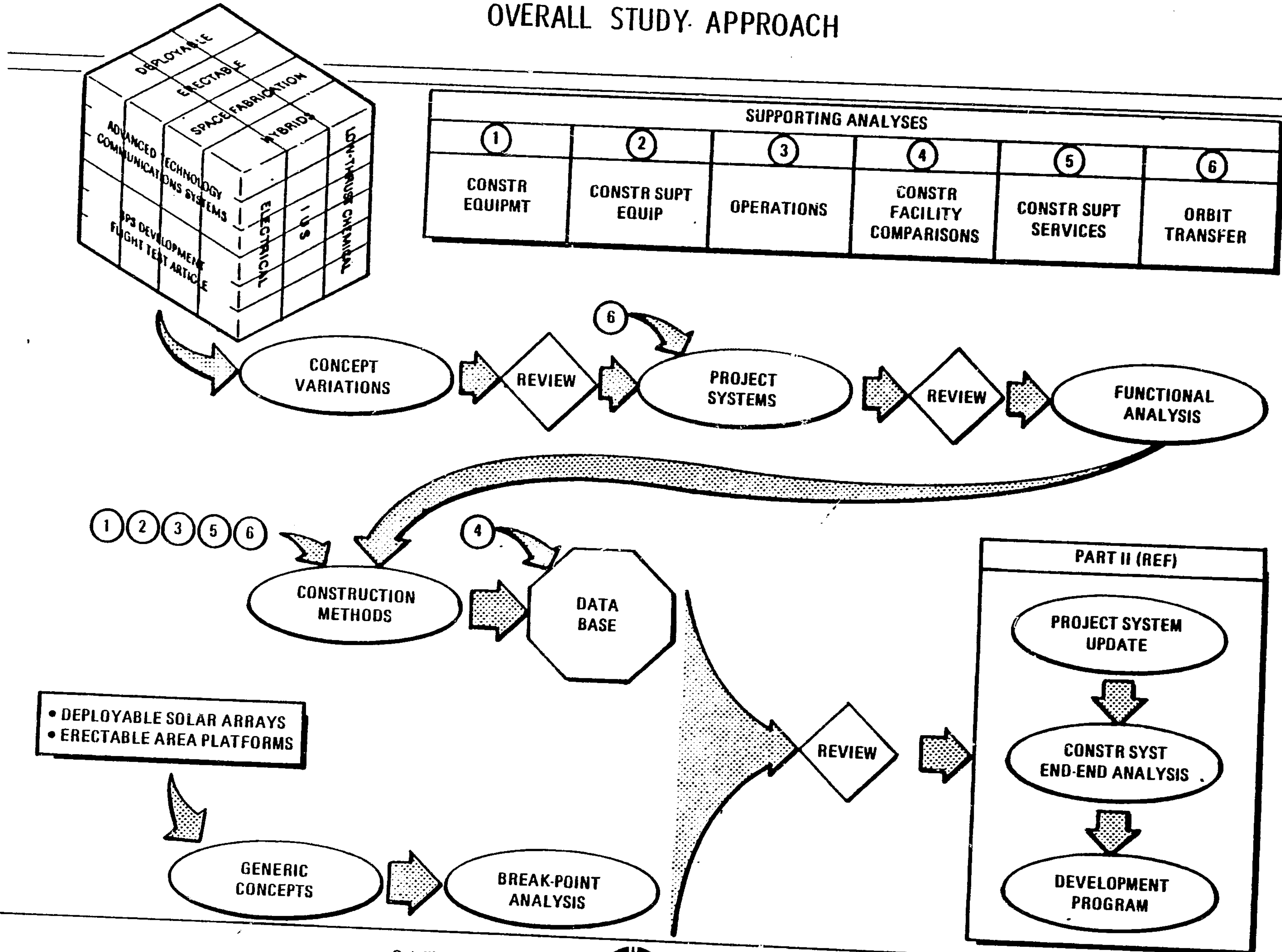
OVERALL STUDY APPROACH

The cube in the upper left hand corner symbolically represents the major dimensions of the study.

At the first project review, 12 December 1979, twenty concept variations representing permutations of the cube were presented. At the second project review, 21 March 1979, design and mission definitions were presented for each of three project systems and construction requirements identified. In the final third of Part I, we have performed analyses of a number of critical construction functions and, for each, have defined one or more methods by which the function (e.g., install a thrust structure sub-assembly on the platform) could be accomplished. These methods, and supporting information, have been entered into the initial release of the Space Construction Data Base.

Generic concepts for deployable solar arrays and low aspect ratio (area) erectable platforms have also been evaluated. For each, estimates have been made of the "break points" (e.g., storage limits in the cargo bay) at which these generic types would be applicable.

OVERALL STUDY APPROACH



ACCOMPLISHMENTS - PART I

This chart summarizes the principal accomplishments of Part I.

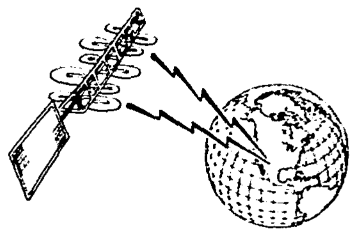
As reported in our earlier reviews, we extended JSC's in-house Solar Power Satellite (SPS) study in respect to a flight test article which would verify the construction and microwave (power) antenna technologies. For the advanced communications project, we conducted a user survey of requirements for a multi-beam system which could supplant a number of individual satellite services in the early 90's. To assist this activity, our Collins Transmission Systems Division performed a study of future requirements and generated a scenario for the evolution of the platform system.

In terms of platform system design, we generated 20 concept packages covering deployable, erectable, and space-fabricated types of construction for the two projects - and several types (low-thrust chemical, IUS, and solar electric) of orbit transfer propulsion. Three of these concepts were defined in sufficient detail (e.g., line sizes, number of connections, etc.) to generate construction requirements.

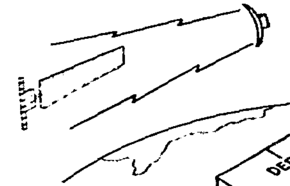
The initial issue of Space Construction Data Base has been released; as additional construction analyses are performed, new data will be incorporated into the "loose-leaf" format of this document.

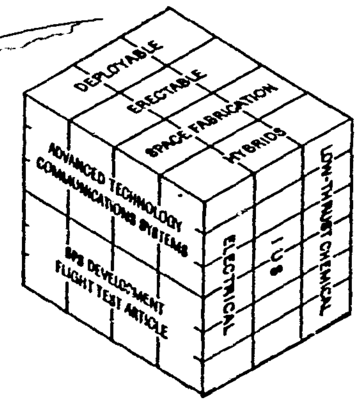
We have generated two design concepts for deployable solar arrays and have determined the cargo bay packaging and power limits of these designs. We have also evaluated the merits of area erectable platforms in comparison to linear (long slender) configurations.

ACCOMPLISHMENTS - PART I



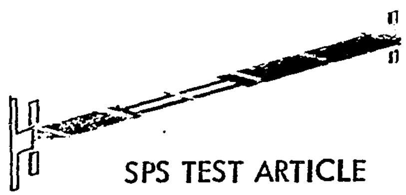
☆ ESTABLISHED PROJECT REQUIREMENTS
- SPS TEST ARTICLE
- ADVANCED COMMUNICATIONS



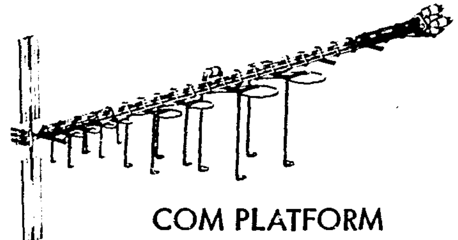


☆ GENERATED 20 PROJECT VARIATIONS
— CONCEPT DESIGN
— STRUCTURAL ANALYSIS
— PROUPULSION INSTALLATION
— WEIGHTS

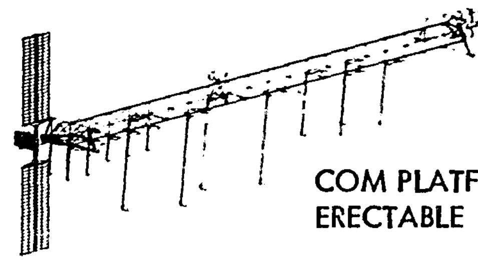
☆ DEFINED THREE PROJECT SYSTEMS



SPS TEST ARTICLE



COM PLATFORM
SPACE FABR

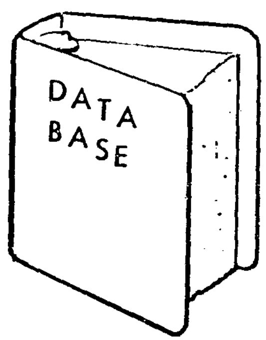


COM PLATFORM
ERECTABLE

☆ GENERATED CONSTRUCTION DATA BASE

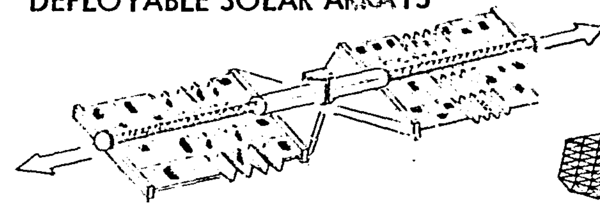
—22 CONSTRUCTION FUNCTIONS

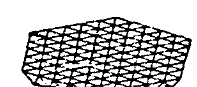
—47 CONSTRUCTION METHODS



☆ EVALUATED GENERIC CONCEPTS

DEPLOYABLE SOLAR ARRAYS





AREA ERECTABLE STRUCTURES

WHAT HAVE WE LEARNED?

No Text Required.

WHAT HAVE WE LEARNED?

LONG SLENDER CONFIGURATIONS ARE IDEAL FOR CONSTRUCTION AND SUITABLE FOR EARTH-ORIENTED MISSIONS

Long, slender (linear) platforms are favored over low aspect-ratio (area) configurations for the study projects (SPS Test Article and Advanced Communications) and are considered advantageous for most earth-oriented missions requiring large constructions out of the Shuttle orbiter.

Our basic position is that the linear platforms are easier to build and that, in all other respects (e.g., structural performance, accommodation of systems and payloads), the linear configurations are comparable to the area configurations.

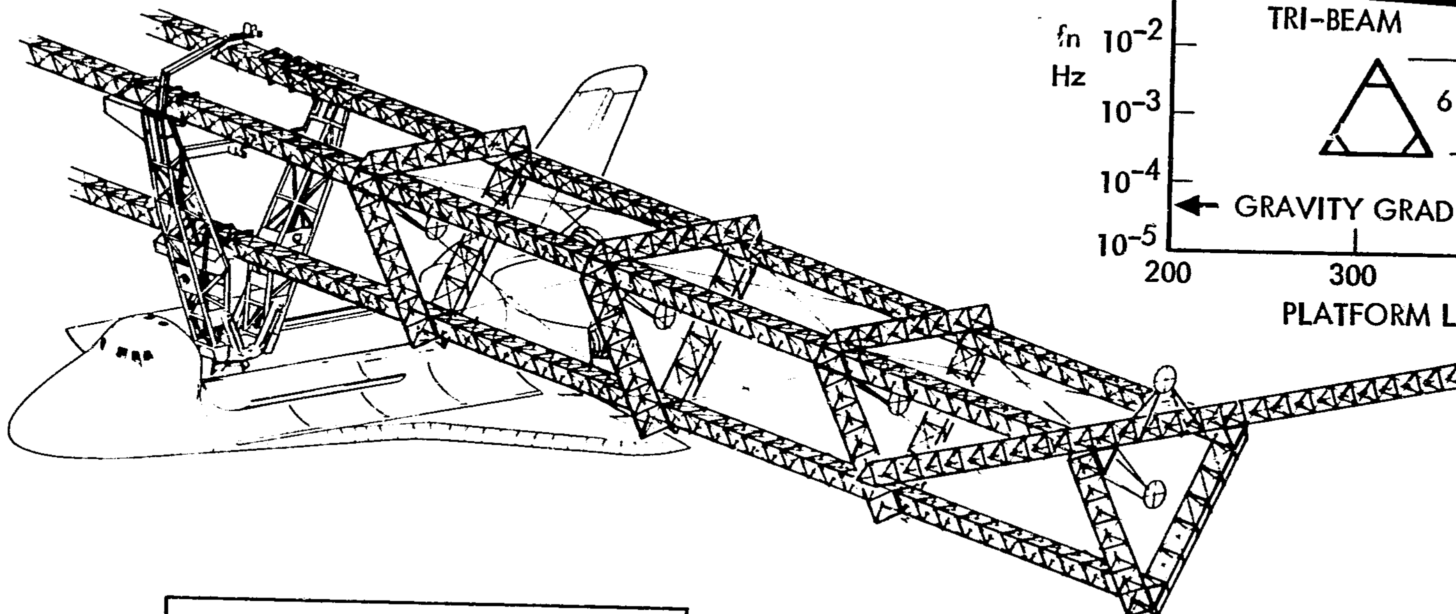
The cross-section of the linear platform should be sized to minimize the dimensions of the supporting fixture system and to enhance reach and access to the work station. Correspondingly, all work should be done on the fixture system near the cargo bay. Our studies have demonstrated that linear configurations can satisfy these criteria and yet have sufficient structural stiffness at more than twice the length of the project platforms.

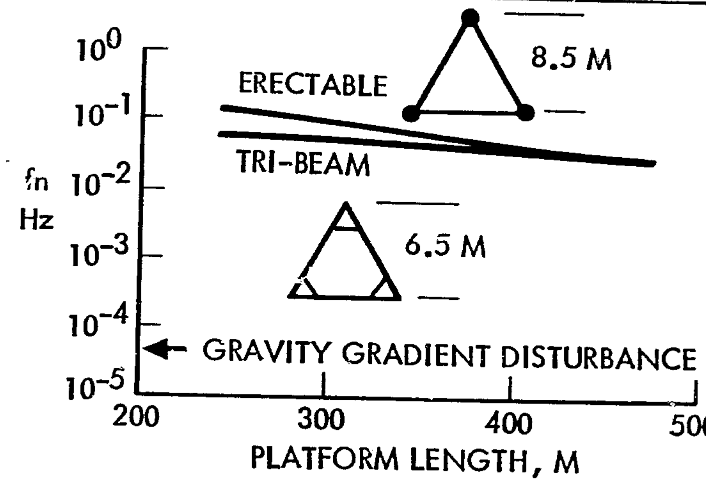
In our special-emphasis study of area erectable platforms, we noted that the area configurations required at least as many structural elements and joints as did the equivalent linear platform. The area platform was shown to be stiffer,* but both platforms were well above minimum stiffness requirements. Since the structural weights of both platforms were approximately 6% of the total, the differential was considered trivial. The area type was also noted to be less susceptible to thermal and fabrication distortions, but both platforms were well within project requirements.

The linear type also has the advantage of improved integration with the orbiter. A large area system must be constructed "overhead" in the orbiter's X-Y plane to avoid interference with the wing and tail surfaces. This limitation creates problems in terms of reach and visibility—particularly for the installation of systems. The linear type, on the other hand, can be built along the displaced X, Y, or Z axis—whichever most effectively enhances reach, access, and visibility. In addition, translation of the linear platform requires only one axis of movement; the associated mechanisms/operations are therefore simpler than for the two-axis translation required of the area platforms.

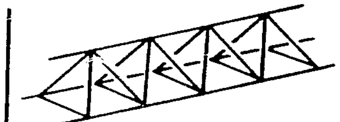
*The linear type was critical in bending; the area type was critical in local flexure of the attached modules.

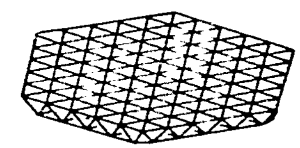
√ LONG SLENDER CONFIGURATIONS ARE IDEAL FOR CONSTRUCTION AND SUITABLE FOR EARTH-ORIENTED MISSIONS





- MINIMIZED WORK VOLUME
- IMPROVES ACCESS
- INTEGRATES WITH ORBITER
- SINGLE AXIS TRANSLATION





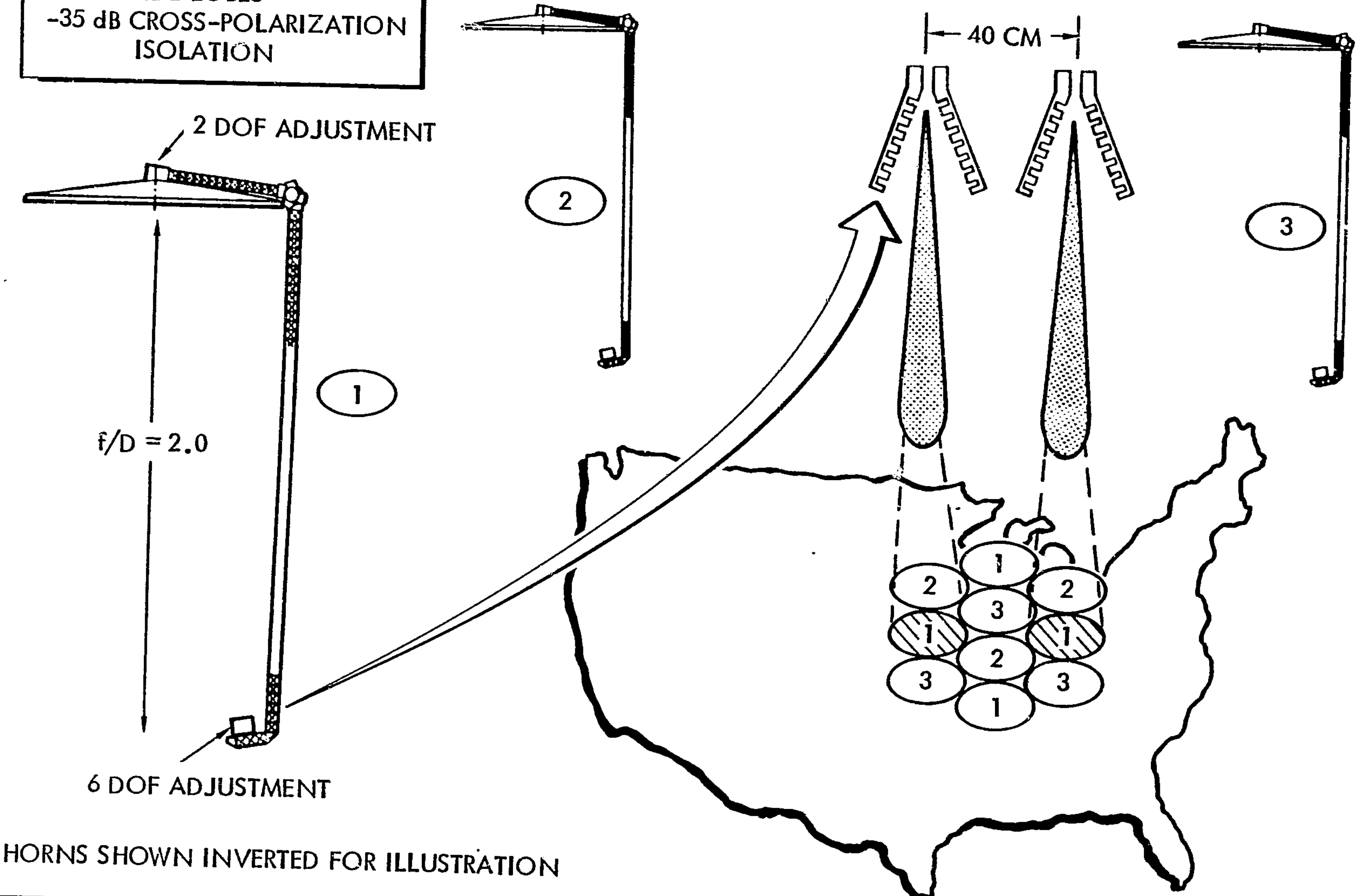
NO PARTS	300	400
STIFFNESS	0.14 Hz	0.21 Hz
WEIGHT	7400 LB	10,400 LB
ACCURACY	7 ARC MIN	5 ARC MIN

HIGH QUALITY COMMUNICATIONS DRIVES MULTIPLE MULTI-BEAM ANTENNAS

In our studies of the Advanced Communications project, we have concluded that multiple off-set feed reflectors, each generating 73 beams, are required to provide full CONUS coverage with good frequency reuse and high quality signal reception. To achieve a quality corresponding to -35 dB side lobes and high cross-polarization isola- tion, we propose the use of scalar horns at the feed. These horns, which are sized/ tailored to the antennas and their carrier frequencies can be installed no closer than 40 cm on centers for the largest (20.5 m) of the antennas. As a consequence, the reflected footprints on the CONUS generated by two adjacent horns in the same feed cluster are separated by roughly 200 nmi. To achieve CONUS coverage in the "open" spaces (2 and 3 on the chart) an additional two antennas (2 and 3) are required, with their horns arrayed to provide interleaving coverage with antenna 1. Pointing of the three complementary antennas to assure interleaved coverage would be by automatic adjustment of each antenna feed system assembly to respond to ground-generated pilot tones.

√ HIGH-QUALITY COMMUNICATIONS DRIVES MULTIPLE MULTI-BEAM ANTENNAS

-35 dB SIDE LOBES
-35 dB CROSS-POLARIZATION ISOLATION



* HORNS SHOWN INVERTED FOR ILLUSTRATION

A DEPLOYABLE SOLAR ARRAY GENERATING OVER 250 KW IS FEASIBLE

A generic study of deployable solar arrays has indicated the feasibility of packaging a system capable of generating at least 250 kW in a single Shuttle launch.

The illustrated concept was judged to be preferable to alternative deployable arrangements in terms of cargo bay storage and deployment mechanisms. Furthermore, the concept is an extrapolation of technology being developed for the power extension package (PEP) to be carried on selected missions aboard orbiter.

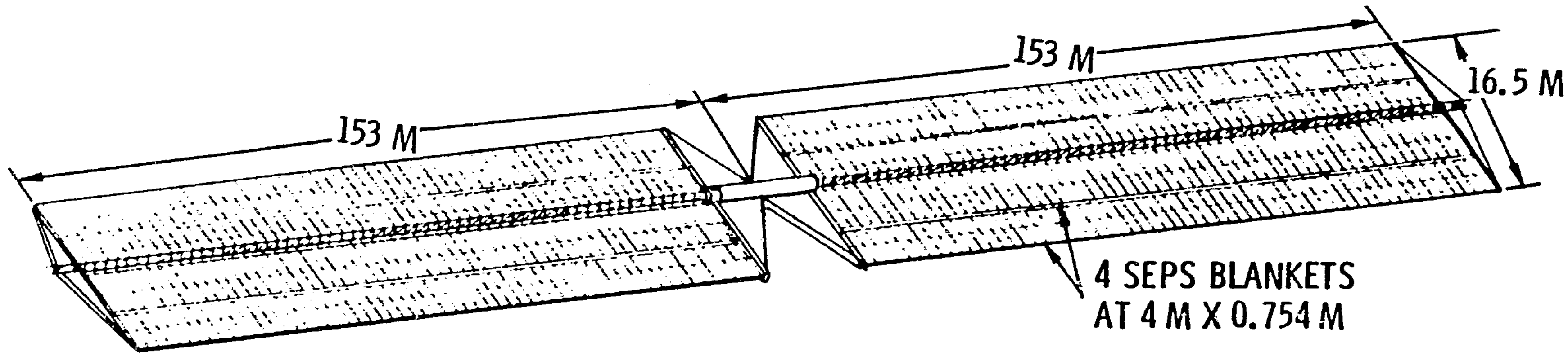
This design would utilize extendable booms to deploy and tension the folded solar blankets from their canisters. The blankets would be comprised of 0.75x4.0 m silicon cell panels currently under development by Lockheed for the SEPS program.

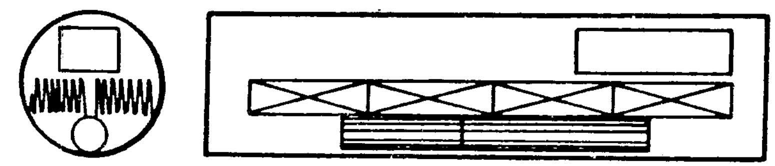
Our packaging layouts showed that the width of the array is driven by the available length within the cargo bay, and the span of the array is driven by the bay diameter. When allowances are made for the cargo bay support cradle and deployment clearances - and, possibly, an OMS kit, sufficient volume is available to package the illustrated system, while remaining well within acceptable CG limits.

Our studies also noted a special problem associated with heat rejection from the back side of the long solar blankets. It was found that up to 50 percent of the array's width could be covered by flat ribbon conductors near the roots of the blankets. The resulting blockage of heat radiation could create high cell temperatures and loss of efficiency. In our Task 1.0 report* we have proposed one possible approach to this issue which warrants special R&D focus.

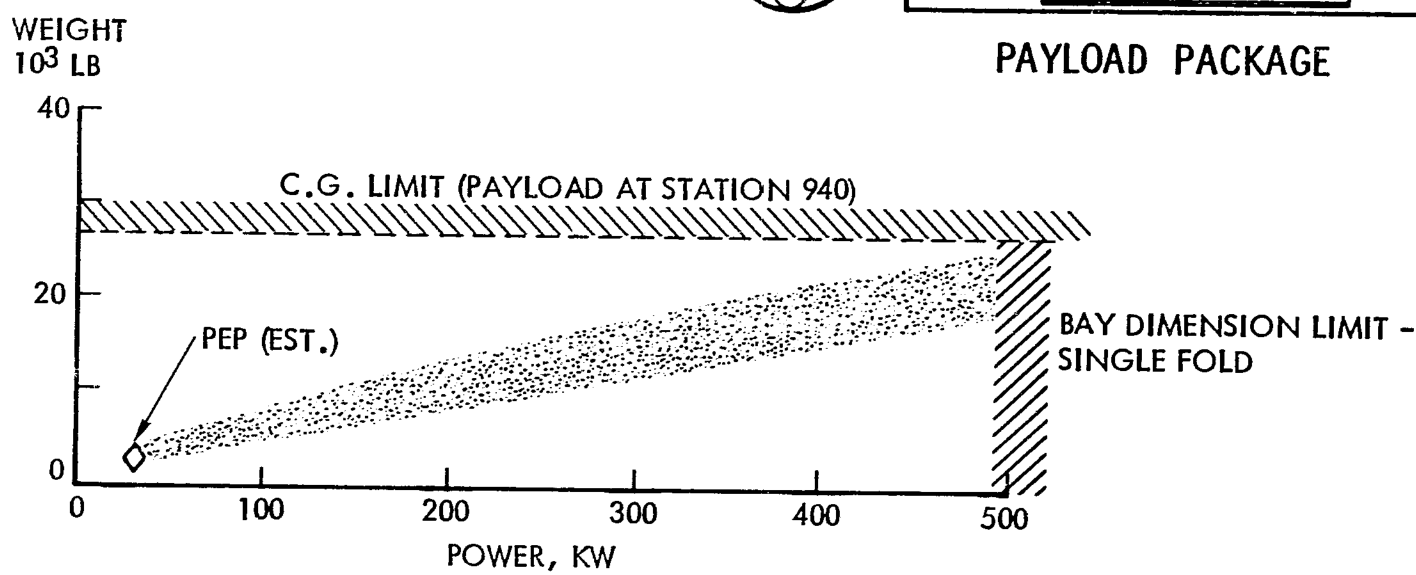
*SSD 79-0077

√ A DEPLOYABLE SOLAR ARRAY GENERATING OVER 250 KW IS FEASIBLE





PAYLOAD PACKAGE



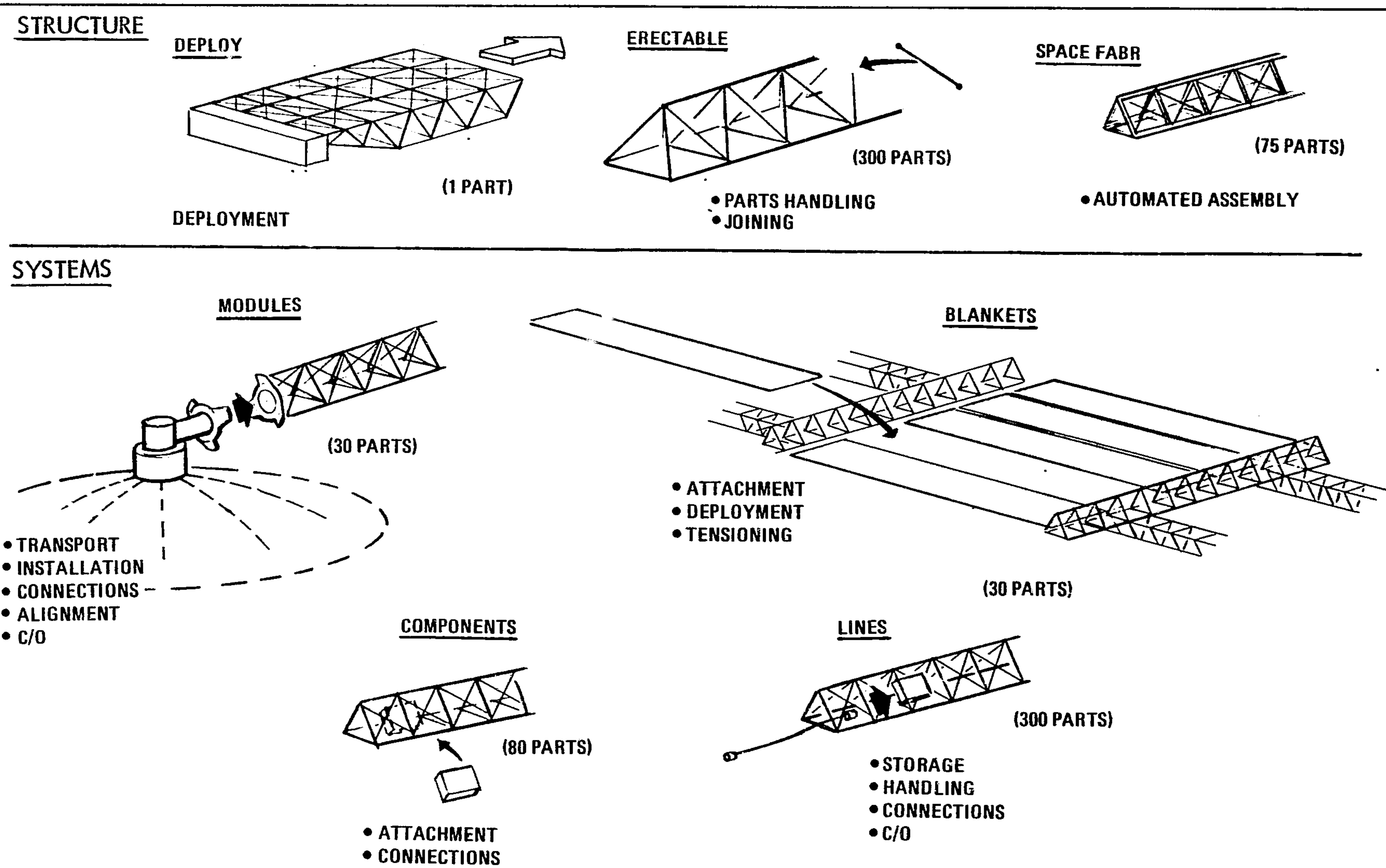
THE INSTALLATION OF SYSTEMS DOMINATES CONSTRUCTION

As noted in the caption of this chart, the installation of systems dominates the construction process. This domination is in terms of numbers and kinds of parts to be assembled, number of connections to be made and requirements for alignment and checkout of the platform elements. This is not to underestimate the importance of the structure - the structural concept tends to drive the basic nature of the construction fixture and forms the framework upon which the systems are installed.

The systems elements comprise more than 90% of the project mass and their installation entails the handling of many different types of elements in a number of special ways. Systems modules and parts come in a variety of different sizes and shapes; some are modules with concentrated mass, some are area shaped membranes, some are electrical lines/cables and small components. Each type of system module can have different numbers of physical and electrical connections, will require different levels of installation precision and will have different checkout requirements.

This wide variety of features and installation requirements will also influence the construction fixture design. Mounting and electrical power/signal interfaces for special construction tools/aids needed for systems installation must be provided. The special tools/aids themselves are driven by the nature of the particular systems/module installation needs for a given project. Also, there is a strong interplay between the logistics requirements for systems and the construction strategy. Systems represent most of deliverable flight hardware and the way they package into the orbiter bay can significantly influence the construction sequence.

√ THE INSTALLATION OF SYSTEMS DOMINATES CONSTRUCTION



* PARTS	* CONNECTIONS	* ALIGNMENT	* CHECKOUT

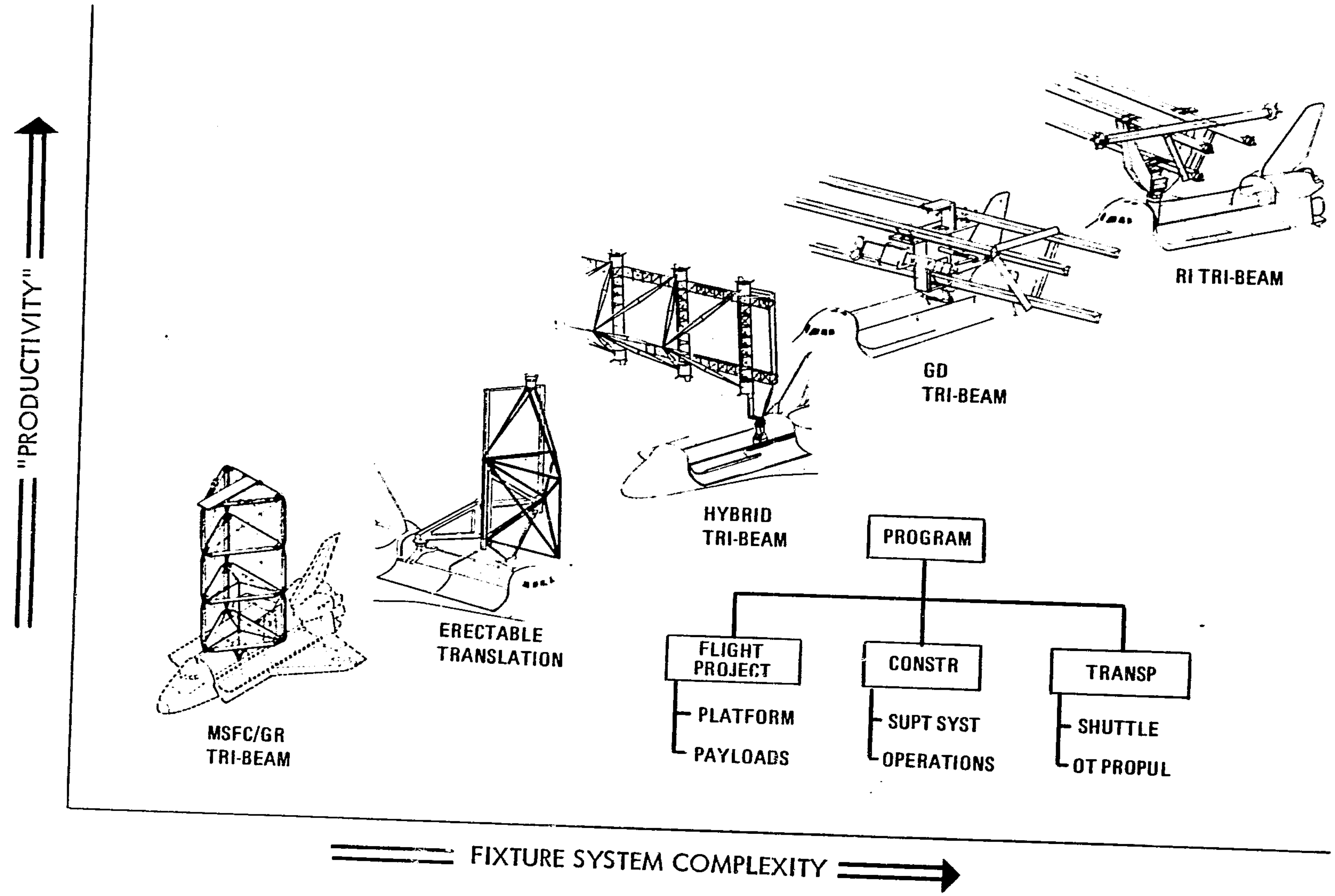
THE CONSTRUCTION FIXTURE SYSTEM IS BIG SWINGER ON PRODUCTIVITY/COST

Another important study finding is: the construction fixture system is the big "swinger" on productivity/cost. By this we mean the relationship between costs and productivity for space construction is strongly affected by the construction fixture system. As illustrated on the accompanying chart there is a correlation between fixture complexity and construction productivity. Several different concepts are shown for the construction of a 3-D structural configuration. The concepts at the bottom left suggest relatively simple fixtures mainly supplying retention and translation of structural members. However, the handling of numerous individual members lengthens the construction process and reduces productivity. The hybrid concept in the middle of the chart has both space fab elements and erectable elements. Thus, it provides increased productivity by virtue of its automated space fab process, but still has some erectable operations. The GD tri-beam concept*, next up the productivity scale, offers the full automation of space fab, but the lack of 2-way translation limits its productivity. The Rockwell tri-beam at the top of the scale also offers the full automation of space fabrication and in addition provides 2-way translation of the completed structure. This uncouples the construction process from orbiter bay packaging and logistics constraints, thereby, improving its productivity potential.

Cost implications are represented by the program elements tree at the lower right of the chart. Flight project costs are not significantly affected by the construction concept. The main drivers on program costs will be the construction system and space transportation. Since the construction fixture is the major element of the construction system and is key to the logistics/construction sequence issues, it tends to dominate the productivity/cost relationship.

*Space Construction Automated Fabrication Experiment Definition Study, Part III Final Briefing, General Dynamics.

√ THE CONSTRUCTION FIXTURE SYSTEM IS BIG SWINGER ON PRODUCTIVITY/COST*



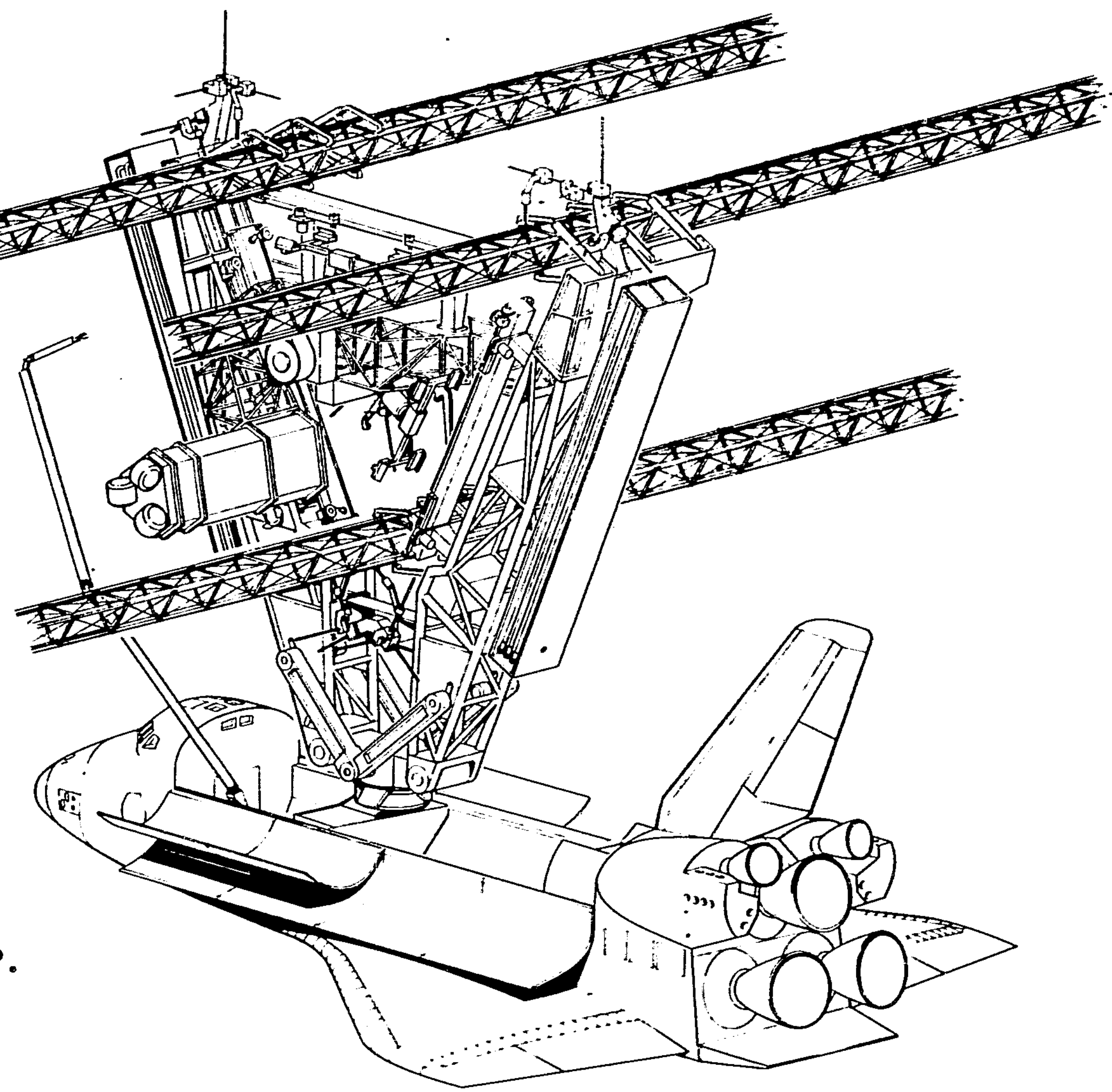
FIXTURE SYSTEM REQUIREMENTS

To illustrate the systems nature of construction fixtures, this chart depicts the diversity of requirements associated with the Rockwell tri-beam concept shown on the preceding chart. Key functional requirements and design drivers are highlighted.

This fixture system serves as the master tool or jig controlling the main dimensions of the tri-beam structure. It must have the capability to accurately position and hold the space fab beam segments during the fabrication and joining process. Also, as mentioned in the preceding chart, the fixture provides two-way translation of the completed structure. This gives repeated access to any location on the structure for subsequent systems installation functions, thereby uncoupling the construction sequence from orbiter bay packaging and related logistics constraints. Berthing and docking interfaces with the orbiter are required for the construction of space projects entailing multiple Shuttle flights. Navigation/berthing aids and untended (between Shuttle flights) attitude control and housekeeping are also required to provide the construction revisit capability. Provisions for a variety of construction-related interfaces are also required. These include: electrical power interfaces with the orbiter and for mechanized construction equipment/aids, signal interfaces for controlling the construction system and operations, EVA monitor and duty stations, parts storage convenient to their usage in the construction process, and mounting/storage provisiions for construction support equipment (e.g., MRWS) which may be left in orbit between visits. In addition to the above requirements, the construction fixture system must be designed for packaging into the orbiter bay.

FIXTURE SYSTEM REQUIREMENTS

- TRANSLATION/ARTICULATION
- DIMENSIONAL CONTROL
- ORBITER DOCKING
- POWER INTERFACE
- CONSTRUCTION CONTROL
- EVA STATION(S)
- PARTS STORAGE
- NAVIGATION/BERTHING AIDS
- UNTENDED ATTITUDE CONTROL
- UNTENDED HOUSEKEEPING
- STORAGE OF CONSTR SUPT EQUIP.
- PACKAGING IN CARGO BAY



SUPPORT EQUIPMENT IN DEVELOPMENT IS SUITABLE FOR SPACE CONSTRUCTION

The major items of support equipment required for the construction of the study flight projects are illustrated.

The RMS (Remote Manipulator System) is an essential part of the construction system for the transport of elements and for selected joining/assembling operations. In general, the reach of the arm is adequate, although certain situations suggest an extended length effector to improve access. In this respect, several special end-effectors will be required to handle a diversity of elements and operations. We have noted a strong need to incorporate an added rotation joint on the upper arm (near the shoulder). This additional articulation will provide a much improved utility of the RMS in a number of construction situations.

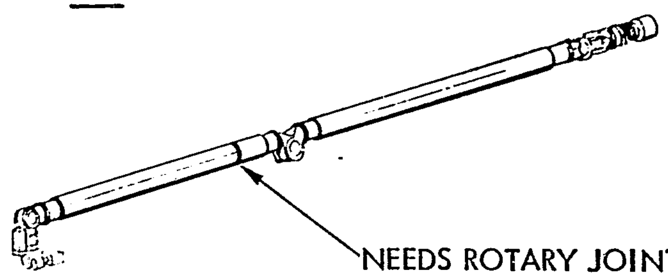
The "Cherry Picker"/Manned Remote Work Station was found to be effective in a number of situations requiring direct vision/visibility and the dexterity offered by man's presence. The MRWS concepts generated by Grumman/JSC appear highly appropriate to these kinds of situations. We have discussed with Grumman the desirability of incorporating an alternate attachment interface which could enhance the utility of the system.

Our studies have assumed the utilization of the General Dynamics beam builder for all space-fabrication operations. We have identified a "desire" to modify the beam - end shearing mechanism to eliminate the cap stubs. This modification would allow the tri-beam cross members to be installed and joined at a single longitudinal station.

The MMU (Manned Maneuvering Unit) has been identified as an effective mode of transporting an EVA astronaut to remote work locations in a selected number of situations. In all respects the MMU appears adequate for the potential tasks.

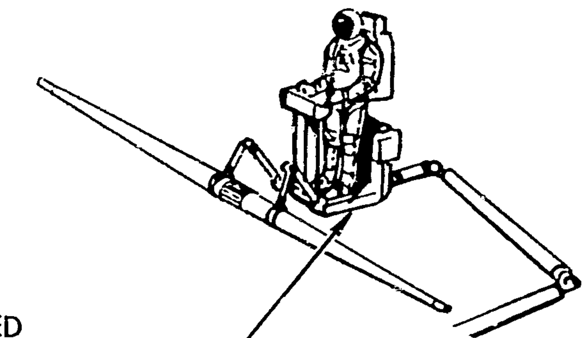
√ SUPPORT EQUIPMENT IN DEVELOPMENT IS SUITABLE FOR SPACE CONSTRUCTION

RMS



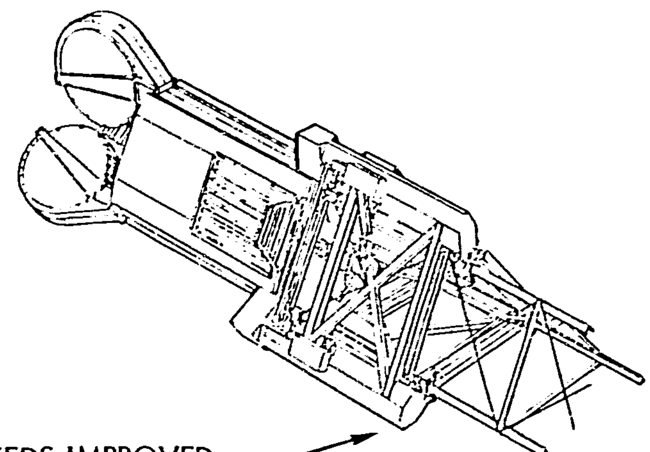
NEEDS ROTARY JOINT

CHERRY PICKER (MRWS)



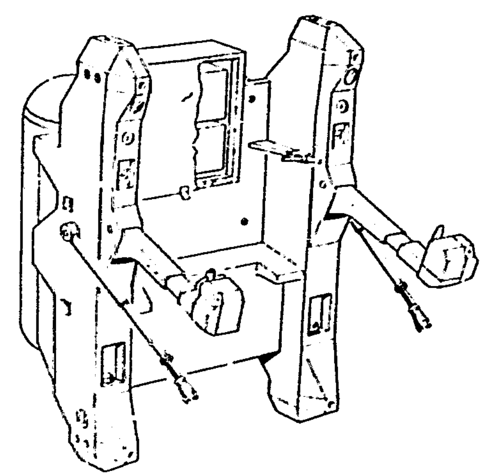
MAY NEED
OPTIONAL ATTACHMENT

BEAM BUILDER



NEEDS IMPROVED
SHEARS

MMU



PLATFORM SYSTEM MUST BE DESIGNED FOR REMOTE SERVICING

The operational life of the communications platform must be at least 20 years to assure an adequate return on the investment cost of the platform. To attain this life span it has been assumed that servicing operations will be performed at regular intervals of 5-7 years. Thus, the design of the platform must be such so as to facilitate servicing/replacement of the batteries, antennas, control moment gyros (CMG's) and other components. The CMG's, which are contained within the system control module, were selected as being representative of items to be serviced. A design concept for the system control module was generated to be compatible with the general servicing concept of using a teleoperator (T/O) type of vehicle with a rotating magazine containing the replacement units. This concept will provide the necessary alignment accuracy to permit the automatic exchange of the CMG's. The selection of the design concept for the servicing mechanism then dictated the basic requirements for the system control module.

As shown on the facing page, the control module has a centrally-located berthing port for the T/O - and the CMG's have been packaged, located and mounted to be compatible with the servicing mode. In addition, the module will be mounted on the platform normal to the longitudinal axis to provide safer access for the T/O.

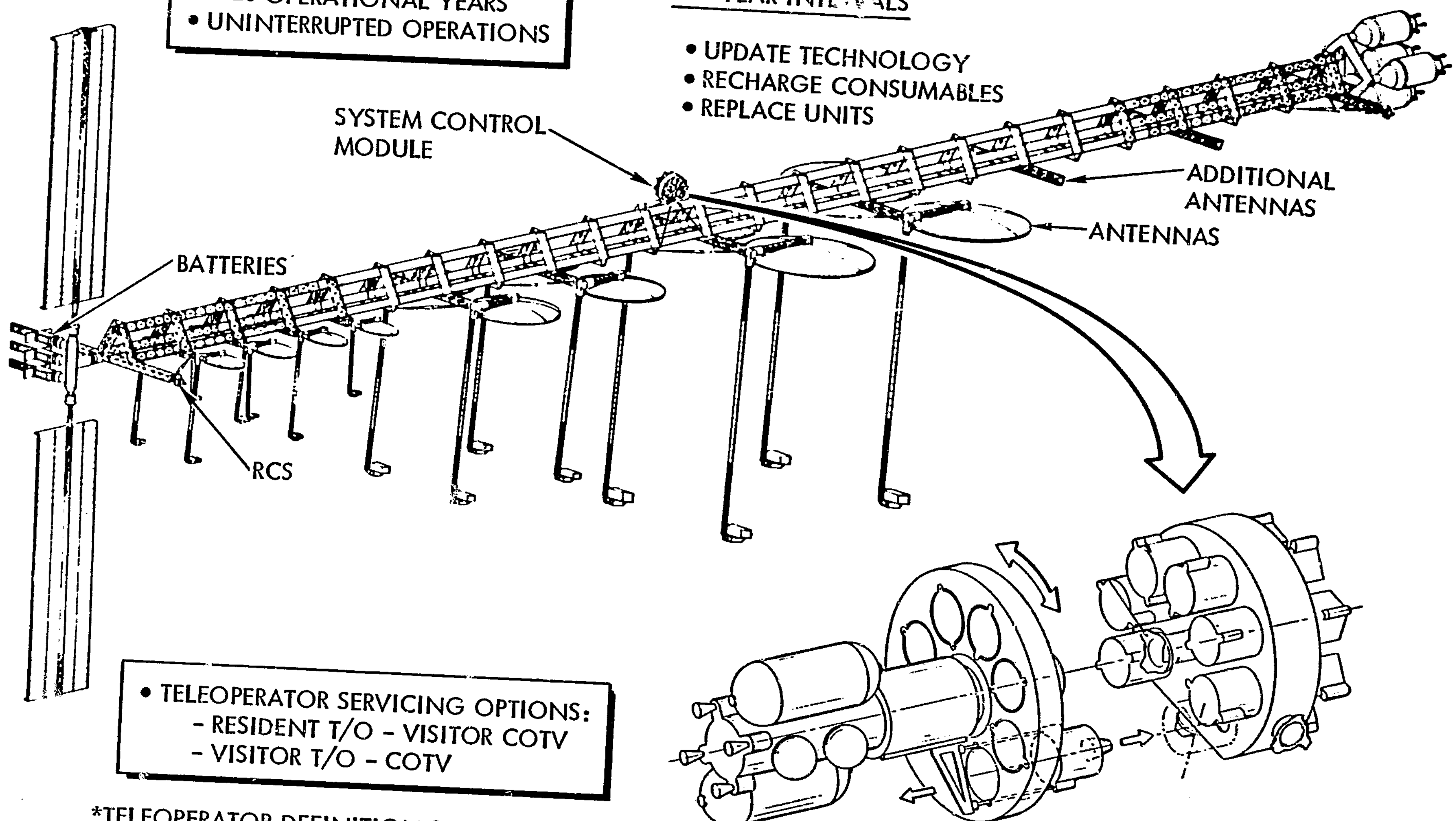
Two servicing concepts have been generated using a T/O. In the first, the T/O is a resident of the platform for its entire life; for servicing operations, a Cargo Orbital Transfer Vehicle (COTV) delivers the space-replaceable items, which are changed out by the T/O. In the second mode; the T/O comes up with the COTV as a visitor and is then returned for reuse or expended.

√PLATFORM SYSTEM MUST BE DESIGNED FOR REMOTE SERVICING

- ≥20 OPERATIONAL YEARS
- UNINTERRUPTED OPERATIONS

5-7 YEAR INTERVALS

- UPDATE TECHNOLOGY
- RECHARGE CONSUMABLES
- REPLACE UNITS



- TELEOPERATOR SERVICING OPTIONS:
  - RESIDENT T/O - VISITOR COTV
  - VISITOR T/O - COTV

*TELEOPERATOR DEFINITION STUDIES REQUIRED

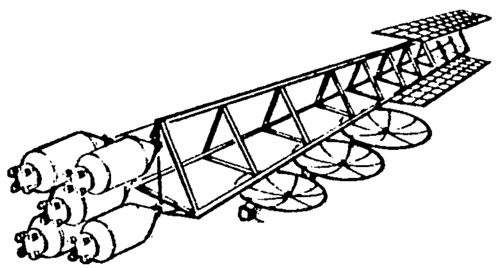
AN ADVANCED CRYOGENIC PROPULSION MODULE IS FAVORED FOR ORBIT TRANSFER

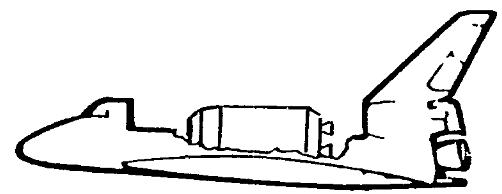
Four basic types of propulsion were investigated to determine their suitability for use in the orbit transfer of the project systems. The principal comparative factors are summarized on the chart. Based on these results, an advanced cryo stage appears to offer the most promise as a general-purpose OTV for use with these systems. Properly designed, the project systems can easily function with moderate thrust loads imposed by the cryo stages. Use of multiple nozzles, judicious staging and/or possible throttling can keep the peak loads down. Control frequencies for thrust steering can be adequately separated from structural bending frequencies for proper stability without excessive ΔV penalties.

The higher thrust loads inherent with the IUS solid motors introduce complications into both the design and the construction of the project systems. Also, its lower I_{sp} performance, like that of the advanced storable, requires significantly more propulsion system weight than the cryo and, thus, many more Shuttle flights for delivery.

Solar electric propulsion (SEP) requires very large (and costly) solar arrays, resulting in excess electrical power over that needed for GEO mission operations. It also requires long trip times—six months or longer—which can lead to significant investment cost increases. The extra trip time over a cryo OTV would defer the operational availability of the project systems, thereby adding 5% or more to the project's cost at today's discount rates. However, with advances in technology and performance to improve its thrust and cost-effectiveness, SEP could be highly competitive for orbit transfer of large area space systems.

√ AN ADVANCED CRYOGENIC PROPULSION MODULE IS FAVORED FOR ORBIT TRANSFER*

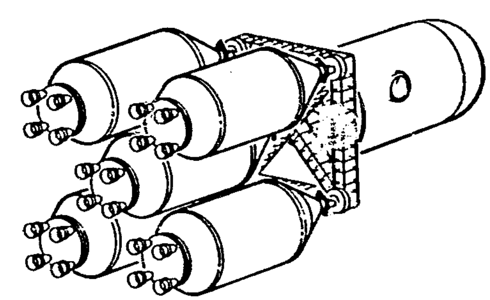




- LO_2/LH_2
- I_{sp} = 467 SEC
- T ≈ 20,000 lb./MODULE
- W ≈ 63,000 LB/MODULE
- 8-WK STORABILITY

	LO THRUST CHEM		IUS	SEP
	CRYO	STORABLE		
$(T/W)_{MAX}$	0.2	0.2	0.9	10^{-4}
NO MODULES	5	10	24	N/A
NO STAGES	2	3	12	N/A
NO LAUNCHES	5	10	12	3-4
IMPACT ON SOLAR ARRAY	HINGING REQUIRED			>5X AREA
IMPACT ON ANTENNAS	PARTIAL DEPLOYMENT			FULL DEPLOY

MOTV?



*IMPROVEMENT IN SEP SPECIFIC THRUST/AREA COULD AFFECT CONCLUSION

ORBITER CAN BE USED AS THE CONSTRUCTION FACILITY - BUT POWER/ENERGY MAY BECOME COST DRIVER

In general, the constraints imposed by orbiter-based construction had small effect on the flight project (platform) systems and their configurations. It must, however, be recalled that the configurations were very much driven by construction/productivity factors*.

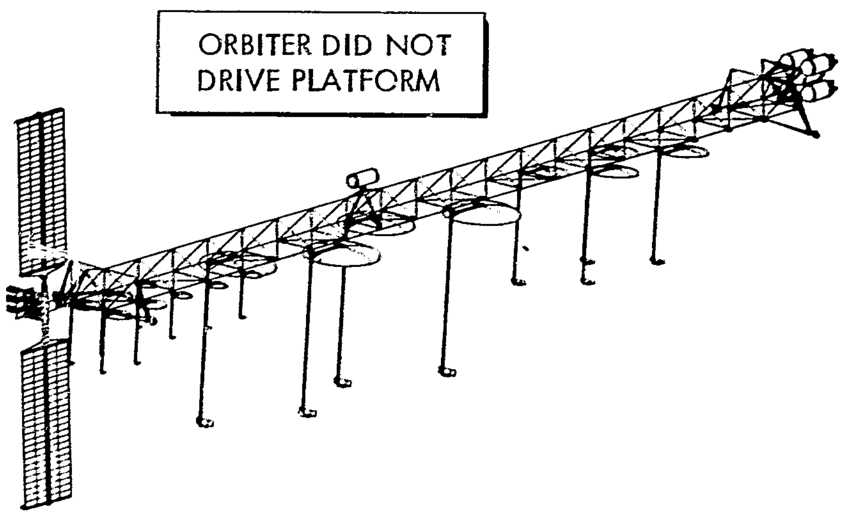
On the other hand, the orbiter constraints did drive the construction system and, particularly, the fixture system design. The location and orientation of the fixture was affected by such factors as physical clearance of the orbiter's mold lines, clear access to the cargo bay, visibility from the aft deck control station, egress by EVA crewmen, and by the position/reach of the RMS.

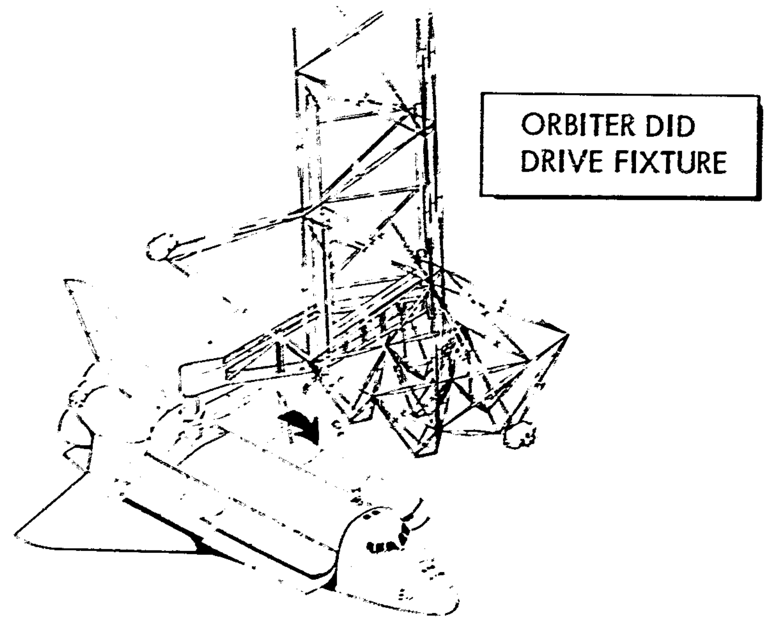
The major implication of using the orbiter as the construction facility is that of power/energy. An investigation of the power requirements for construction suggests 7 kW maximum continuous power from the orbiter may be adequate to supply the major power-consuming equipment**. The lower left hand graph illustrates that the maximum mission time (assuming 7 kW average power) is 9 days with two cryo kits below the cargo bay liner. If this time is inadequate to assemble one orbiter cargo bay of parts, the number of launchings required could be driven by the orbiter's available energy. If we choose to install additional cryo kits, they would displace cargo in the bay - thus, leading to delta launch requirements. Use of PEP (Power Extension Package) may be an effective alternative if the energy limitation prevails - but additional requirements would devolve in terms of a second RMS and potential attitude restrictions.

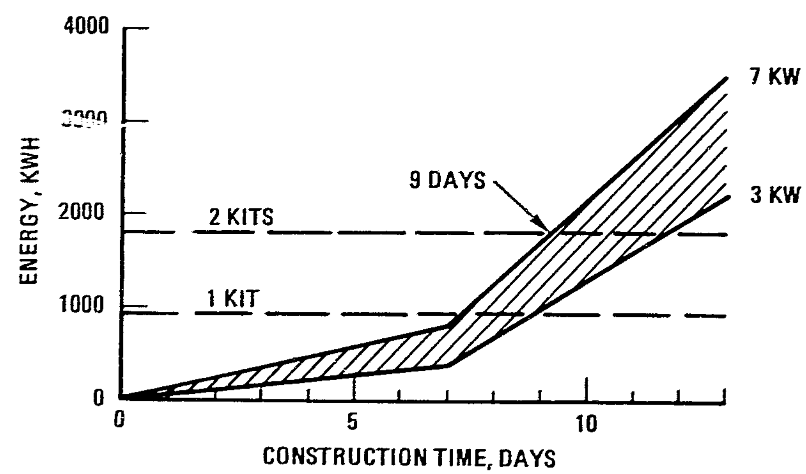
*Long slender configurations are ideal for construction and suitable for earth-oriented missions.

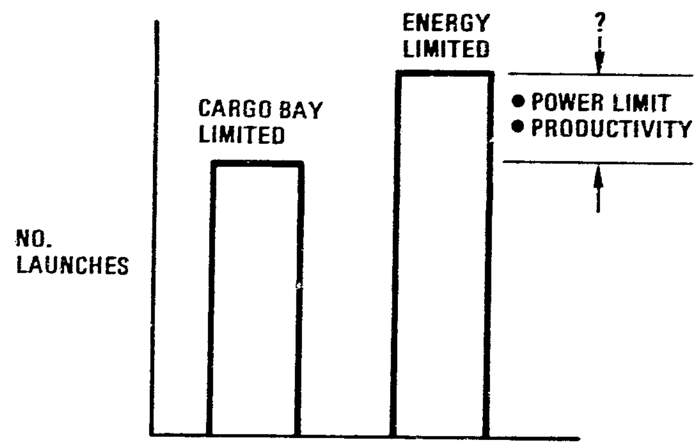
**This premise will be examined in detail during Part II of the study.

√ ORBITER CAN BE USED AS THE CONSTRUCTION FACILITY - BUT POWER/ENERGY MAY BECOME COST DRIVER









A SPACE OPERATIONS CENTER WOULD PRODUCE IMPORTANT BENEFITS

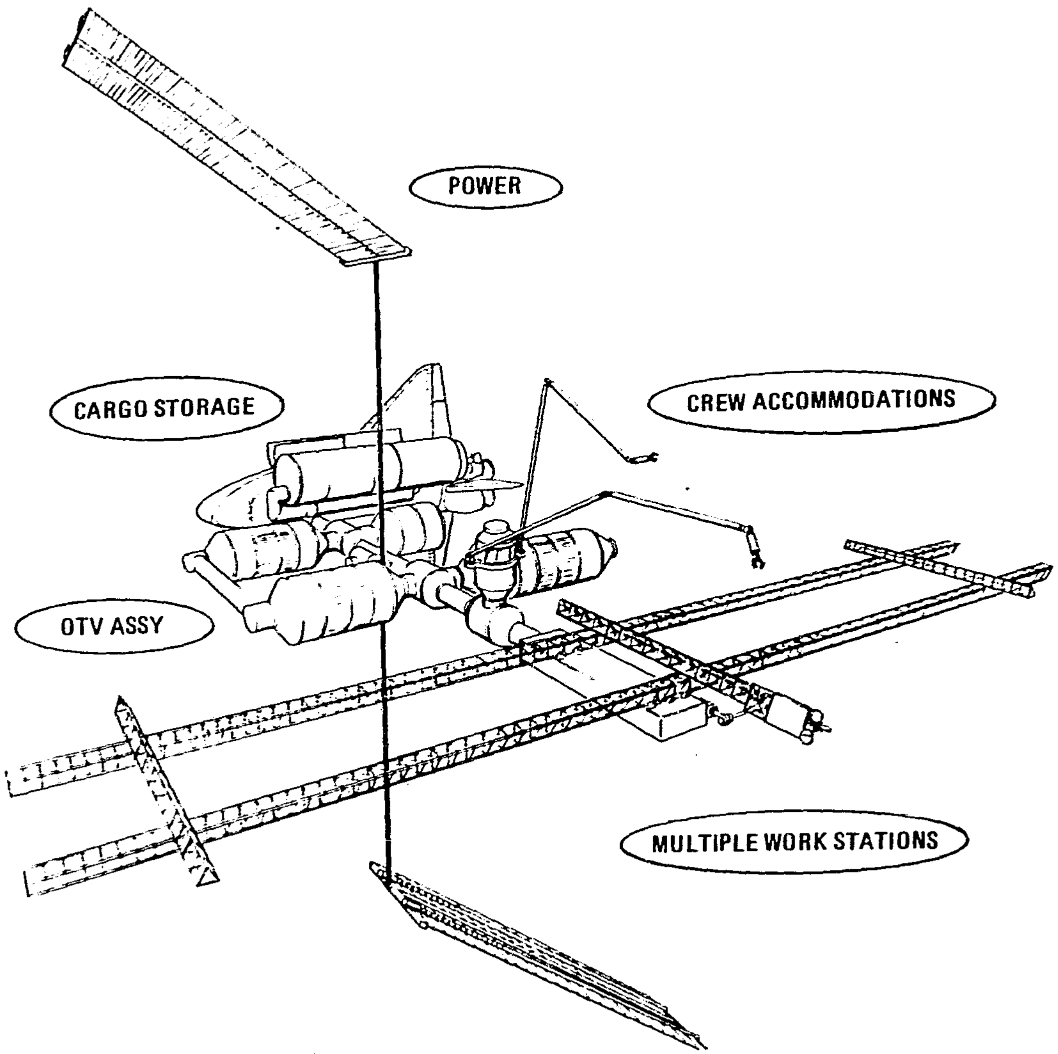
Construction from a Space Operations Center (S.O.C.) could promote the desirable characteristics listed on the chart: (1) Improved Productivity; (2) Improved Shuttle Utilization; and (3) Multi-Project Applications.

Improved productivity would result from continuous construction operations as contrasted with the interrupted construction operations characteristic of construction from the orbiter. The potential for performing sub-assembly operations in parallel with the basic fabrication/assembly operations would also increase productivity. The construction crew could be specifically trained for space construction operations and, with comfortable living quarters, be more productive in their tasks.

The orbiter's role in construction from the S.O.C. would be limited to the transport of cargo/personnel. Consequently, no modifications would be required to the orbiter and, therefore, the launch schedule could be flexible to accommodate the Shuttle operations agenda. Removable cargo cradles would allow pre-packaging on the ground and the capability to be deposited at the S.O.C.. This concept would aid in achieving fast turnaround operations and would simplify S.O.C. logistics.

Different types of construction projects should be accommodated by the S.O.C.. A full hemisphere of space would be allocated to construction to provide good clearance for all anticipated construction projects. The utilization of a space crane with long arms to enhance reach capability is desirable for transport and positioning of various components of construction projects.

√ A SPACE OPERATIONS CENTER WOULD PRODUCE IMPORTANT BENEFITS



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- ☆ IMPROVED PRODUCTIVITY
  - CONTINUOUS OPS
  - PARALLEL OPS
  - CREW SPECIALIZATION
  - CREW COMFORT
- ☆ IMPROVED SHUTTLE UTILIZATION
  - NO KITS/MODS
  - LAUNCH SCHED FLEXIBILITY
  - FAST TURNAROUND
- ☆ MULTI-PROJECT APPLICATION
  - CLEARANCES
  - REACH

SPACE CONSTRUCTION IS A NEW TECHNOLOGY DEMANDING SPECIAL BLEND OF SKILLS

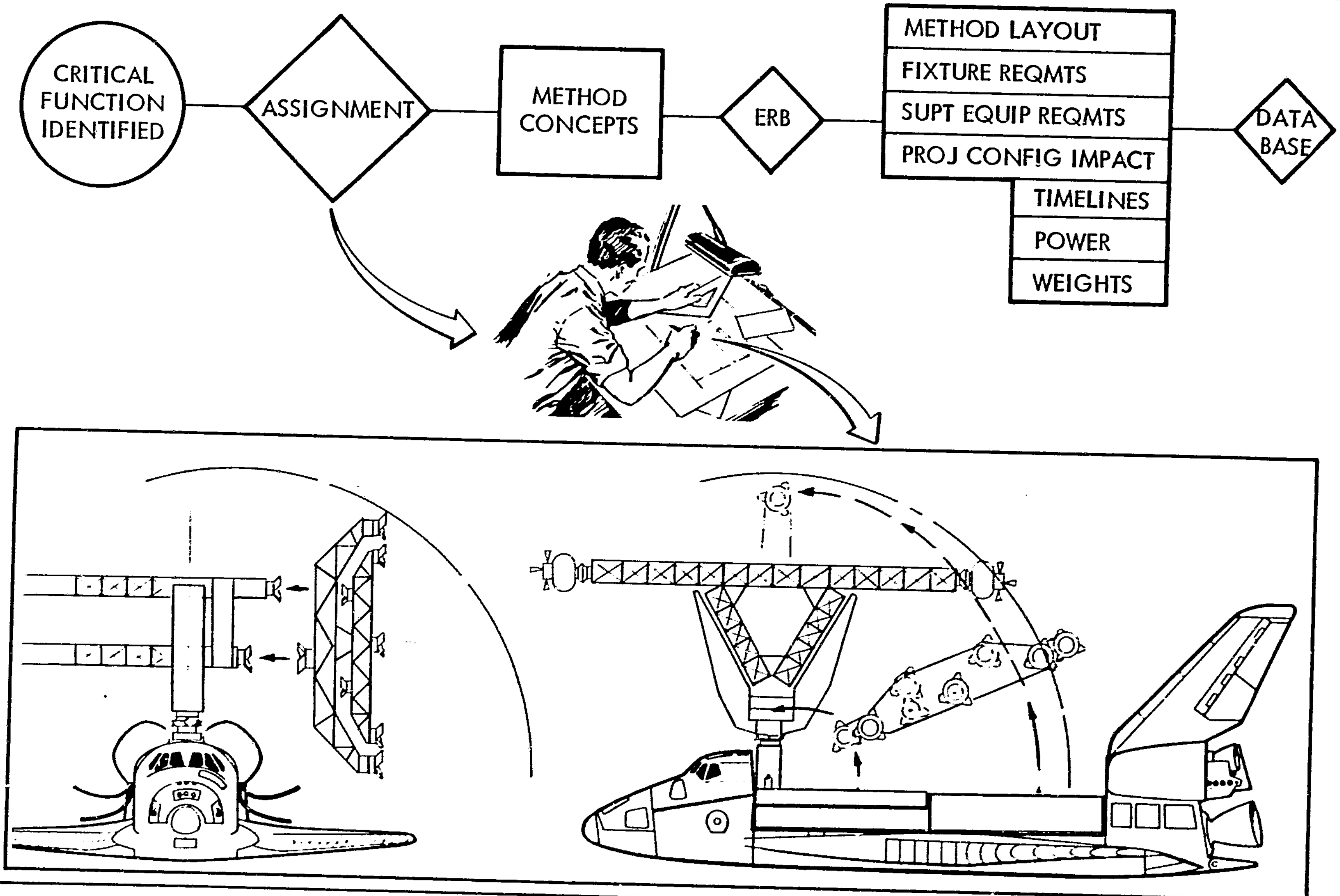
Our most challenging task during Part I has been the generation of practical construction methods by which particular critical functions* could be executed. The product of this task has been the Space Construction Data Base - one of the key objectives of Part I.

Our approach to this task has been to assign a "construction project engineer" for each identified critical function - with the job of presenting candidate concepts to an engineering review board (ERB) and of following up selected concepts with the definition required for the data base. Of particular note here is the blend of skills required of the "construction project engineer" - principally a blend of design and analytic skills. For example, the "CPE" must have the capacity to creatively conceptualize in a complex 3-D framework, to illustrate and draft his concepts for understanding by others, to develop the kinematic motions required by the construction processes, to appreciate the hardware impacts of his concepts upon existing and planned mechanisms and support equipment, and to appreciate the impacts of his methods upon the crew and other operational components of the construction system.

The synthesis of these skills in single individuals has been an important part of the learning process of Part I.

*An example of a critical function: Installation and tensioning of diagonal cords in a cord-braced structure.

√ SPACE CONSTRUCTION IS A NEW TECHNOLOGY DEMANDING SPECIAL BLEND OF SKILLS



OUR POSITION

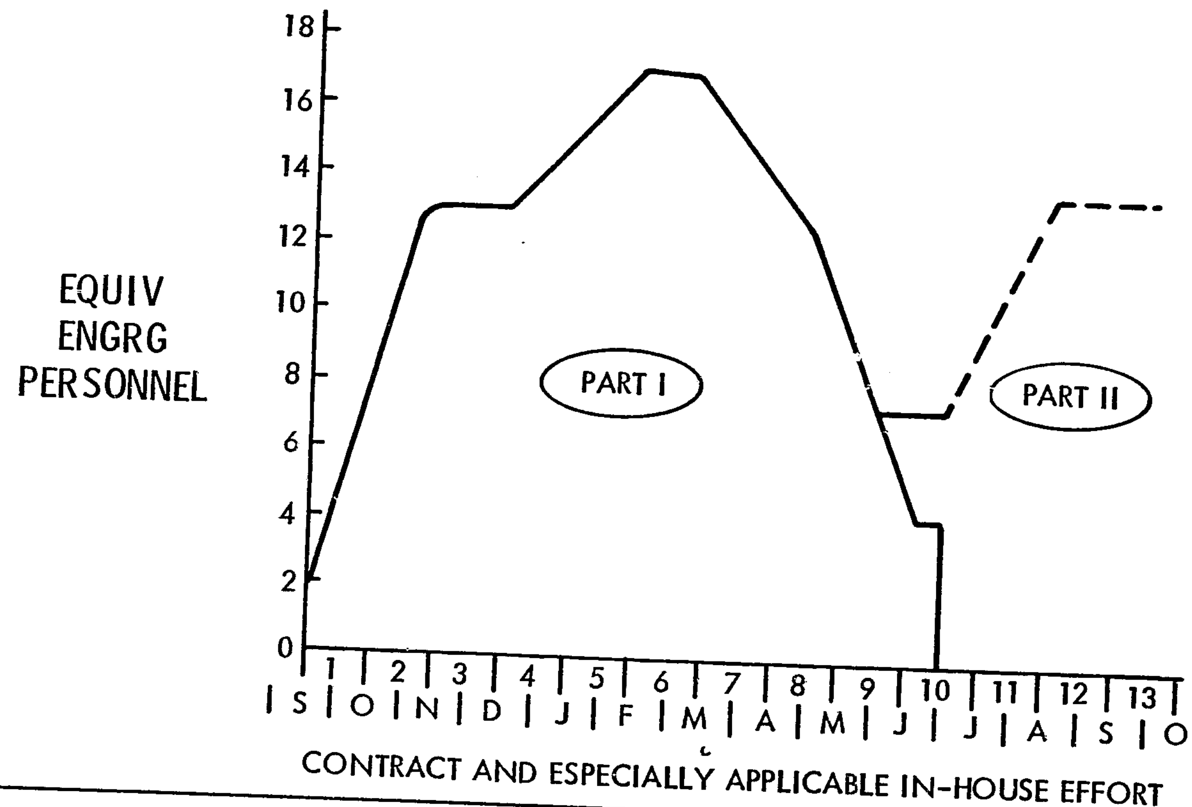
At this juncture, the completion of Part I, we have released the initial issue of the Space Construction Data Base which provides the prime input to the end-to-end construction analysis of Part II. We have generated a base of construction knowledge (see concluding charts) and expertise in this new technology. In accomplishing these ends, approximately 20,000 engineering man-hours have been applied during Part I. As described in a later chart, we have begun the Part II activity.

OUR POSITION

☆ CONSTRUCTION DATA BASE

☆ LEARNING/EXPERIENCED PERSONNEL

☆ BEGINNING PART II



PART II

The project of interest for Part II is entitled *Applications Technology Platform (ATP)*. As illustrated, the ATP is conceived to be a 1980's program equivalent to the 1970's ATS-F experiment. The ATS-F spacecraft was launched into GEO in the summer of 1974 to demonstrate several key technologies and to develop new space communications capabilities. ATS, which is terminating operations this year, has been a highly successful program and supported by a wide base of users: PBS, HEW, DOI, State/Indian Government, FAA, Maritime Administration, NOAA, National Academy of Sciences.

As in the case of the ATS program, ATP would be aimed at a wide base of user support and at technology developments needed for subsequent operational systems. Particular emphasis would be given to developing the technologies and capabilities for constructing, transporting, servicing, and operating a multi-mission platform. Major emphasis would also be directed toward payload/mission development tests in support of SPS and advanced space communication systems—and, possibly, large radiometer and space-based surveillance systems.

In Task 5.0* we shall use the project and construction system definitions generated in Part I as a basis to develop and compare three candidate concepts for the ATP. These concepts will be similar in overall platform configuration, but will differ in construction. Concurrent with Task 5.0, Task 6.0 will be initiated with a survey of potential users of the ATP. Contacts will be made with the common communications carriers and with government agencies who may have technological or development needs which could be, in part, satisfied by tests aboard an ATP. The mission analysis subtask will generate the ATP requirements in terms of power, attitude, servicing, data management, command/control, payload installation, orbit transfer, and orbit maintenance.

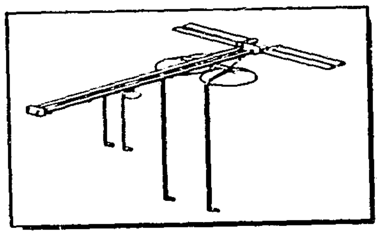
With the selection of an ATP concept and its associated mission/system requirements, the preliminary design, Task 7.0, can be initiated. As a result of our experience during Part I, we plan to conduct the construction end-to-end analysis, Task 8.0, in parallel with the preliminary design. The products of Tasks 7.0 and 8.0 will be inputs to the concluding planning and costing tasks of the study. In addition, new or revised construction methods defined during Task 8.0 will be entered into an updated revision of the Construction Data Base.

*Part II tasks numbered consecutively as an extension of the first four tasks conducted under Part I.

PART II

ANALOGY

APPLICATIONS TECHNOLOGY PLATFORM (ATP)



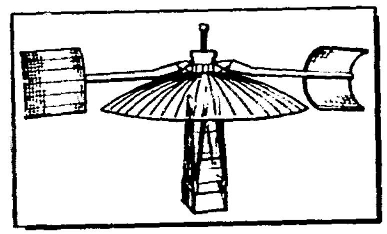
PAYLOAD/MISSION DEVELOPMENT (CANDIDATES)

- ADVANCED COMM (MULTI-BEAM SYS)
- SPS
- RADIOMETRY
- SPACE-BASED SURVEILLANCE
- RADIO ASTRONOMY

TECHNOLOGY DEVELOPMENT

- SPACE CONSTRUCTION
- ORBIT TRANSFER PROPULSION
- ORBIT SERVICING

APPLICATIONS TECHNOLOGY SATELLITE (ATS)

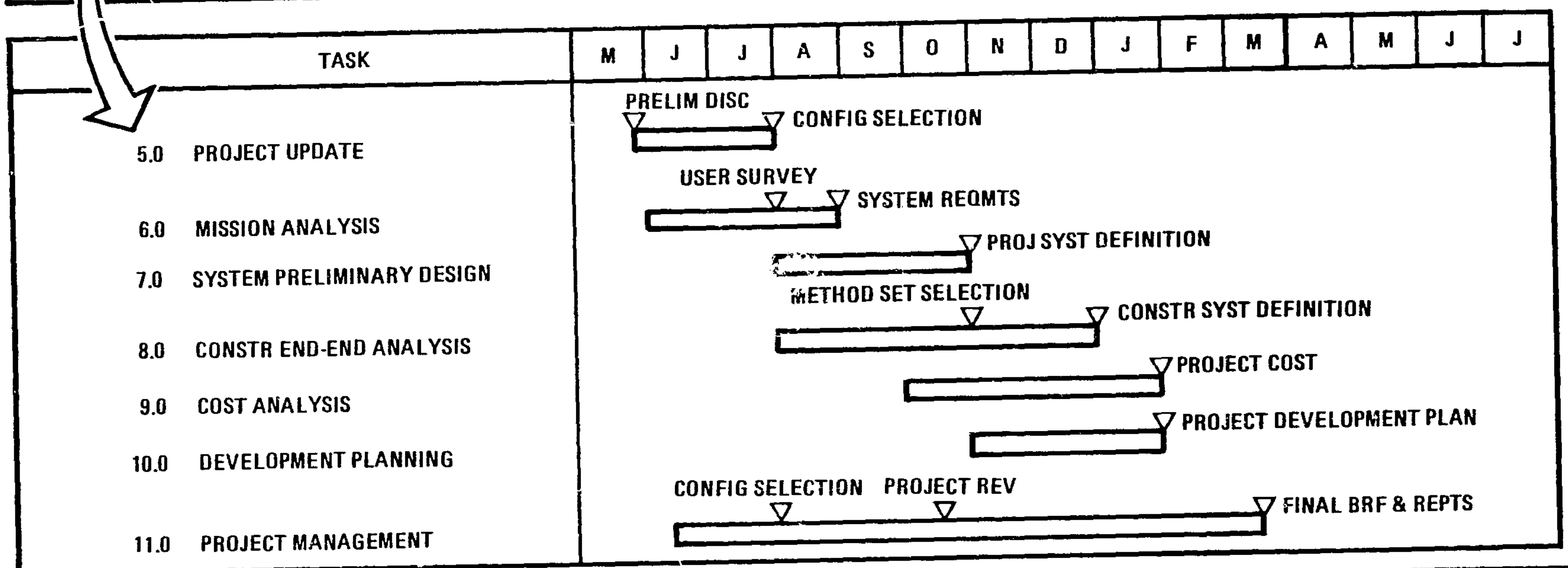


PAYLOAD/MISSION DEVELOPMENT

- ADVANCED COMM (HIGH-GAIN ANTENNA
- EARTH RESOURCES
- SPACE SCIENCES

TECHNOLOGY DEVELOPMENT

- 30-FT DEPLOYABLE REFLECTOR
- ATTITUDE CONTROL
- ORBIT STATION KEEPING



CONCLUSION

CONCLUSION

No text required.

CONCLUSION

PLATFORM CONFIGURATION

- LINEAR ARRANGEMENT PREFERRED FOR EARTH MISSIONS
- DEPTH DRIVEN BY CONSTRUCTION REQUIREMENTS
- LENGTH DRIVEN BY PAYLOAD ACCOMMODATIONS
- ERECTABLE AND SPACE-FABRICATED STRUCTURES ARE SMALL FRACTION OF PLATFORM WEIGHT
- SYSTEMS INSTALLATION DESIGN DRIVEN BY CONSTRUCTION AND SERVICING

SOLAR ARRAYS

- SEPS DEPLOYMENT ARRANGEMENT BEST
- >250 KW CAN BE PACKAGED IN SINGLE LAUNCH
- HEAT REJECTION MAY BE PROBLEM

SPS MICROWAVE ANTENNA

- 280 KW ARRAY CAN BE PACKAGED IN SINGLE LAUNCH
- SURFACE ACCURACY IS DRIVER

CONCLUSION (CONT.)

No text required.

CONCLUSION (CONT.)

COMMUNICATIONS ANTENNAS

- 20-30 m DIAMETER MAXIMUM REQUIRED
- HIGHEST QUALITY FROM MULTIPLE MULTI-BEAM ANTENNAS
- OFF-SET FED REFLECTORS ARE BEST
- BEAM POINTING CONTROL BY GROUND LOOP TO FEED

ORBIT TRANSFER

- $T/W \approx 0.2$ OPTIMAL FOR PROJECT CONFIGURATIONS
- ADVANCED LO_2/LH_2 PROPULSION MODULE LOOKS BEST
- BUT TECHNOLOGY MAY SHIFT ADVANTAGE TO SEP
- THRUST VECTORING EFFECTS CAN BE MINIMIZED
- INSTALLATION OF PROPULSION MODULES SHOULD BE DONE AT SHUTTLE ORBIT

CONCLUSION (CONT.)

No text required.

CONCLUSION (CONT.)

SUPPORT SERVICES

- ATTITUDE CONTROL NOT REQUIRED FOR CONSTRUCTION
- SOME ATTITUDE DAMPING REQUIRED FOR REVISIT
- REVISIT VELOCITY/ATTITUDE RATES REQUIRE PRECISION CONTROL
- POWER MAY BE DRIVEN BY ILLUMINATION FOR OBSTACLE AVOIDANCE

ORBITER

- CAN PROBABLY BUILD THE DEFINED PROJECTS
- DID NOT DRIVE THE PROJECT CONFIGURATIONS
- DOES DRIVE THE CONSTRUCTION FIXTURE SYSTEM
- CAN PROBABLY REJECT WASTE HEAT
- MAY REQUIRE MODS FOR REVSIT CONTROL AND NITROGEN
- POWER/ENERGY LIMITATIONS MAY DRIVE COSTS
- WILL REQUIRE SPACE-REMOVABLE CARGO CRADLE

CONCLUSION (CONT.)

No text required.

CONCLUSION (CONT.)

CONSTRUCTION

- INSTALLATION OF SYSTEMS DOMINATES
- EVA (E.G., MRWS) MAY BE PRODUCTIVE FOR CONSTRUCTION OPERATIONS
- CONSTRUCTION STRATEGY/LOGISTICS FAVORS TWO-WAY TRANSLATION ON FIXTURE
- SPACE FABRICATION HAS SUBASSEMBLY POTENTIAL
- STUDIES ARE REQUIRED OF TELEOPERATOR SERVICING OPTIONS

CONSTRUCTION SUPPORT

- CONSTRUCTION FIXTURE SYSTEM IS KEY COST ISSUE
- CONSTRUCTION FIXTURE DRIVEN BY STRUCTURAL CONFIGURATION, SYSTEMS INSTALLATIONS, AND BY ORBITER
- CURRENTLY PLANNED SUPPORT EQUIPMENT IS SUITABLE
- SOME SPECIAL EQUIPMENT/TOOLS REQUIRED

CONCLUSION (CONT.)

No text required.

CONCLUSION (CONT.)

SPACE OPERATIONS CENTER

- WOULD BENEFIT CONSTRUCTION PRODUCTIVITY
- WOULD BENEFIT SHUTTLE UTILIZATION
- WOULD BE APPLICABLE TO MULTIPLE PROJECTS

SPACE CONSTRUCTION ANALYSIS

- REQUIRES SPECIAL BLEND OF SKILLS
- METHOD INTEGRATION WILL BE THE CHALLENGE

✓ PART I DOCUMENTATION DRAFT COMPLETE

✓ PART II HAS BEGUN